Chapter Nine

VERTICAL ALIGNMENT

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Chapter Nine

VERTICAL ALIGNMENT

9-1.0 DESIGN PRINCIPLES AND PROCEDURES

9-1.01 General Controls for Vertical Alignment

As discussed elsewhere in Chapter Nine, the design of vertical alignment involves, to a large extent, complying with specific limiting criteria. These include maximum and minimum grades, sight distance at vertical curves and vertical clearances. In addition, the designer should adhere to certain general design principles and controls that will determine the overall safety of the facility and will enhance the aesthetic appearance of the highway. These design principles for vertical alignment include:

1. Consistency. Use a smooth grade line with gradual changes, consistent with the type of highway and character of terrain, rather than a line with numerous breaks and short lengths of tangent grades.

2. Environmental Impacts. Vertical alignment should be properly coordinated with environmental impacts (e.g., encroachment onto wetlands).

3. Long Grades. On a long ascending grade, it is preferable to place the steepest grade at the bottom and flatten the grade near the top. It is also preferable to break the sustained grade with short intervals of flatter grades.

4. Intersections. Maintain moderate grades through intersections to facilitate turning movements. See Chapter Eleven for specific information on vertical alignment through intersections.

5. Roller Coaster. Avoid using “roller-coaster” type profiles. Roller-coaster profiles are where the horizontal alignment is generally straight and roadway profile closely follows a rolling natural ground line. This type of profile may be proposed in the interest of economy, but it is aesthetically undesirable and may be more difficult to drive.

6. Broken-Back Curvature. Avoid “broken-back” grade lines (two crest or sag vertical curves separated by a short tangent). One long vertical curve is more desirable.

7. Sags. Avoid using sag vertical curves in cut sections unless adequate drainage can be provided.

8. Coordination with Natural/Man-Made Features. The vertical alignment should be properly coordinated with the natural topography, available right-of-way, utilities, roadside development and natural/man-made drainage patterns.

9-1.02 Coordination of Horizontal and Vertical Alignment

Horizontal and vertical alignment should not be designed separately, especially for projects on new alignment. Their importance demands that the designer carefully evaluate the interdependence of the two highway design features. This will enhance highway safety and improve the facility's operation. The following should be considered in the coordination of horizontal and vertical alignment:

1. Balance. Curvature and grades should be in proper balance. Maximum curvature with flat grades or flat curvature with maximum grades does not achieve this desired balance. A compromise between the two extremes produces the best design relative to safety, capacity, ease and uniformity of operations and aesthetics.

2. Coordination. Vertical curvature superimposed upon horizontal curvature (i.e., vertical and horizontal P.I.'s at approximately the same stations) generally results in a more pleasing appearance and reduces the number of sight distance restrictions. Successive changes in profile not in combination with the horizontal curvature may result in a series of humps visible to the driver for some distance, which may produce an unattractive design. However, under some circumstances, superimposing the horizontal and vertical alignment must be tempered somewhat by Comment #'s 3 and 4 as follows.

3. Crest Vertical Curves. Do not introduce sharp horizontal curvature at or near the top of pronounced crest vertical curves. This is undesirable because the driver cannot perceive the horizontal change in alignment, especially at night when headlight beams project straight ahead into space. This problem can be avoided if the horizontal curvature leads the vertical curvature or by using design values which well exceed the minimums.

4. Sag Vertical Curves. Do not introduce sharp horizontal curves at or near the low point of pronounced sag vertical curves or at the bottom of steep vertical grades. Because visibility to the road ahead is foreshortened, only flat horizontal curvature will avoid an undesirable, distorted appearance. At the bottom of long grades, vehicular speeds often are higher, particularly for trucks and erratic operations may occur, especially at night.

5. Intersections. At intersections, horizontal and vertical alignment should be as flat as practical to provide designs that produce sufficient sight distance and gradients for vehicles to slow or stop. See Chapter Eleven.

6. Divided Highways. On divided facilities with wide medians, it is frequently advantageous to provide independent alignments for the two one-way roadways. Where traffic justifies a divided facility, a superior design with minimal additional cost generally can result from the use of independent alignments.

7. Residential Areas. Design the alignment to minimize nuisance factors to neighborhoods. Generally, a depressed facility makes the highway less visible and reduces the noise to adjacent residents. Minor adjustment to the horizontal alignment may increase the buffer zone between the highway and residential areas.

8. Aesthetics. Layout the alignment in such a way to enhance attractive scenic views of rivers, rock formations, parks, golf courses, etc. The highway should head into rather than away from those views that are considered to be aesthetically pleasing. The highway should fall towards those features of interest at a low elevation and rise toward those features that are best seen from below or in silhouette against the sky.

The designer should coordinate the layout of the horizontal and vertical alignment as early as practical in the design process. Alignment layouts are typically completed after the topography and ground line have been drafted. The designer should use the computer visualization programs within CADD to visualize how the layout will appear in the field. The designer should review several alternatives to ensure that the most pleasing and practical design is selected.

9-2.0 GRADES

9-2.01 Terrain (Definitions)

1. Level. Highway sight distances are either long or could be made long without major construction expense. The terrain is generally considered to be flat, which has minimal impact on vehicular performance.

2. Rolling. The natural slopes consistently rise above and fall below the roadway grade and, occasionally, steep slopes present some restriction to the desirable highway alignment. In general, rolling terrain generates steeper grades, causing trucks to reduce speeds below those of passenger cars.

3. Mountainous. Longitudinal and transverse changes in elevation are abrupt and benching and side hill excavations are frequently required to provide the desirable highway alignment. Mountainous terrain aggravates the performance of trucks relative to passenger cars, resulting in some trucks operating at crawl speeds.

In Connecticut, only the rolling level terrain criteria will be applicable. Even though a roadway may pass through a level or hilly site, the State as a whole is still considered to be rolling terrain.

9-2.02 Critical Length of Grade

In addition to the maximum grade, the designer must consider the length of the grade. The critical length of grade is the maximum length of a specific upgrade on which a loaded truck can operate without an unreasonable reduction in speed. The highway gradient in combination with the length of grade will determine the truck speed reduction on upgrades. The following will apply to the critical length of grade:

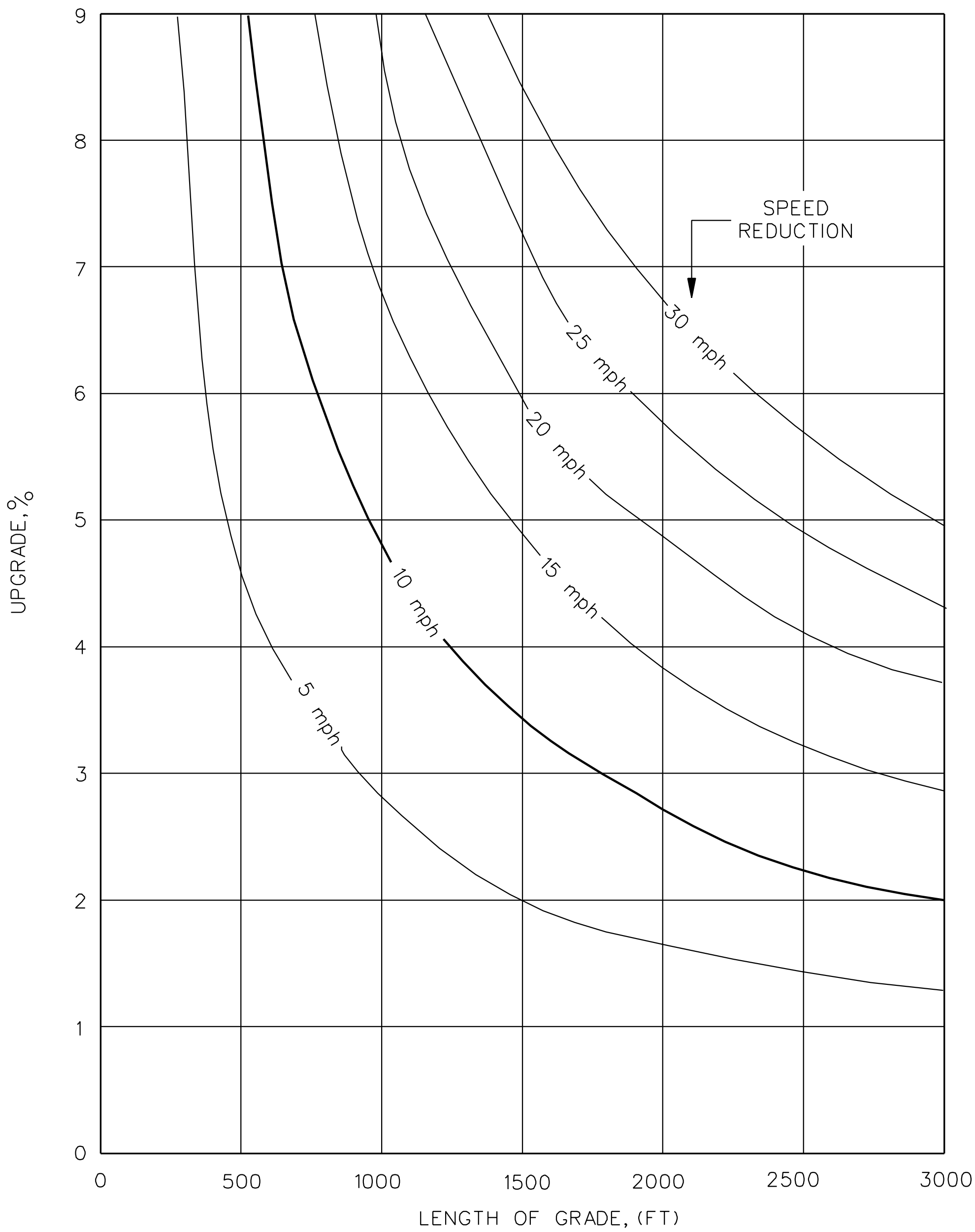
1. Design Vehicle. For critical-length-of-grade determinations, the Department has adopted the 200-lb/hp truck as the most representative design vehicle for Connecticut.

2. Criteria. Figure 9-2A provides the critical lengths of grade for a given percent grade and acceptable truck speed reduction. Although Figure 9-2A is based on an initial truck speed of 70 mph, it applies to any design speed. For design purposes, use the 10 mph speed reduction curve to determine if the critical length of grade is exceeded.

3. Measurement. Vertical curves are part of the length of grade. Figure 9-2B illustrates how to measure the length of grade to determine the critical length of grade from Figure 9-2A.

4. Highway Types. The critical-length-of-grade criteria apply equally to two-lane or multi-lane highways and apply equally to urban and rural facilities.

5. Application. If the critical length of grade is exceeded, the designer should either flatten the grade, if practical, or should evaluate the need for a truck-climbing lane (see Section 9-2.04).



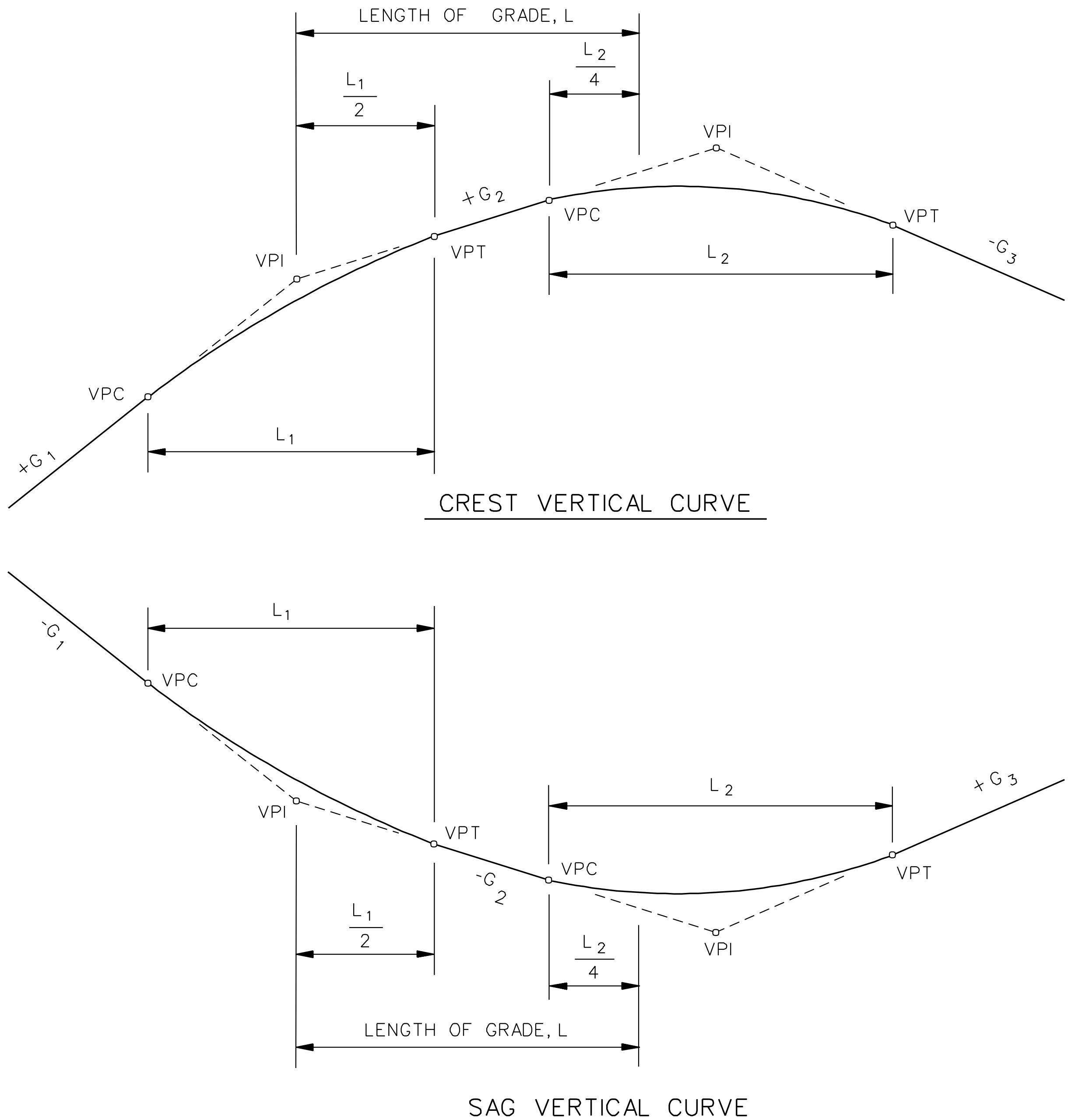
Notes:

1. *Typically, the 10 mph curve will be used.*

2. *Figure based on a truck with initial speed of 70 mph. However, it may be used for any design speed.*

CRITICAL LENGTH OF GRADE
(200-lb/hp Truck)

Figure 9-2A



Notes:

1. *For vertical curves where the two tangent grades are in the same direction (both upgrades or both downgrades), 50% of the curve length will be part of the length of grade.*

2. *For vertical curves where the two tangent grades are in opposite directions (one grade up and one grade down), 25% of the curve length will be part of the length of grade.*

3. *The above diagram is included for illustrative purposes only. Broken-back curves are to be avoided wherever practical.*

MEASUREMENT FOR LENGTH OF GRADE

Figure 9-2B

* * * * * * * * * *

Example 9-2.1

Given: Level Approach
G = + 4%
L = 1500 ft (length of grade)
Rural Arterial

Problem: Determine if the critical length of grade is exceeded.

Solution: Figure 9-2A yields a critical length of grade of 1250 ft for a 10-mph speed reduction. The length of grade (L) exceeds this value. Therefore, the designer should flatten the grade, if practical, or evaluate the need for a climbing lane.

9-2.03 Maximum and Minimum

The highway gradient will significantly impact vehicular operations and safety. The Department has adopted criteria for maximum gradient based on functional classification, urban/rural location, design speed and project scope of work. These values are presented in Chapters Two, Four and Five. Flatter grades should be used wherever practical.

The minimum longitudinal gradient is 0.5%. This applies to all highways with or without curbs.

9-2.04 Truck-Climbing Lanes

9-2.04.01 Warrants

A truck-climbing lane may be warranted to allow a specific upgrade to operate at an acceptable level of service. A truck-climbing lane will generally be warranted if the following conditions are satisfied:

1. the critical length of grade is exceeded for the 10 mph speed reduction curve (see Figure 9-2A; and
2. one of the following conditions exists:
   a. the level of service (LOS) on the upgrade is E or F, or
   b. there is a reduction of two or more LOS when moving from the approach segment to the upgrade; and
3. the construction costs and the construction impacts (e.g., environmental, right-of-way) are considered reasonable.

Truck-climbing lanes may also be warranted where the above criteria are not met if, for example, there is adverse crash experience on the upgrade related to slow-moving trucks. In addition, on four-lane freeways if the speed profile reveals an operating speed of less than 30 mph at any point, a climbing lane will be warranted regardless of the results of the capacity analysis.

9-2.04.02 Capacity Analysis

The objective of the capacity analysis procedure is to determine if the warranting criteria in Section 9-2.04.01 are met. Accomplish this by calculating the service flow rate for each LOS level (A through D) and comparing that to the actual flow rate on the upgrade. Because a LOS worse than D warrants a truck-climbing lane, it is not necessary to calculate the service flow rate for LOS E.

The designer should analyze the operations on the grade using the procedures set forth in the *Highway Capacity Manual*. Note that the default values for determining the appropriate passenger car equivalent (E) values in the *Highway Capacity Software* (HCS) are acceptable for determining the LOS on climbing lanes (i.e., the default truck in the HCS is acceptable).

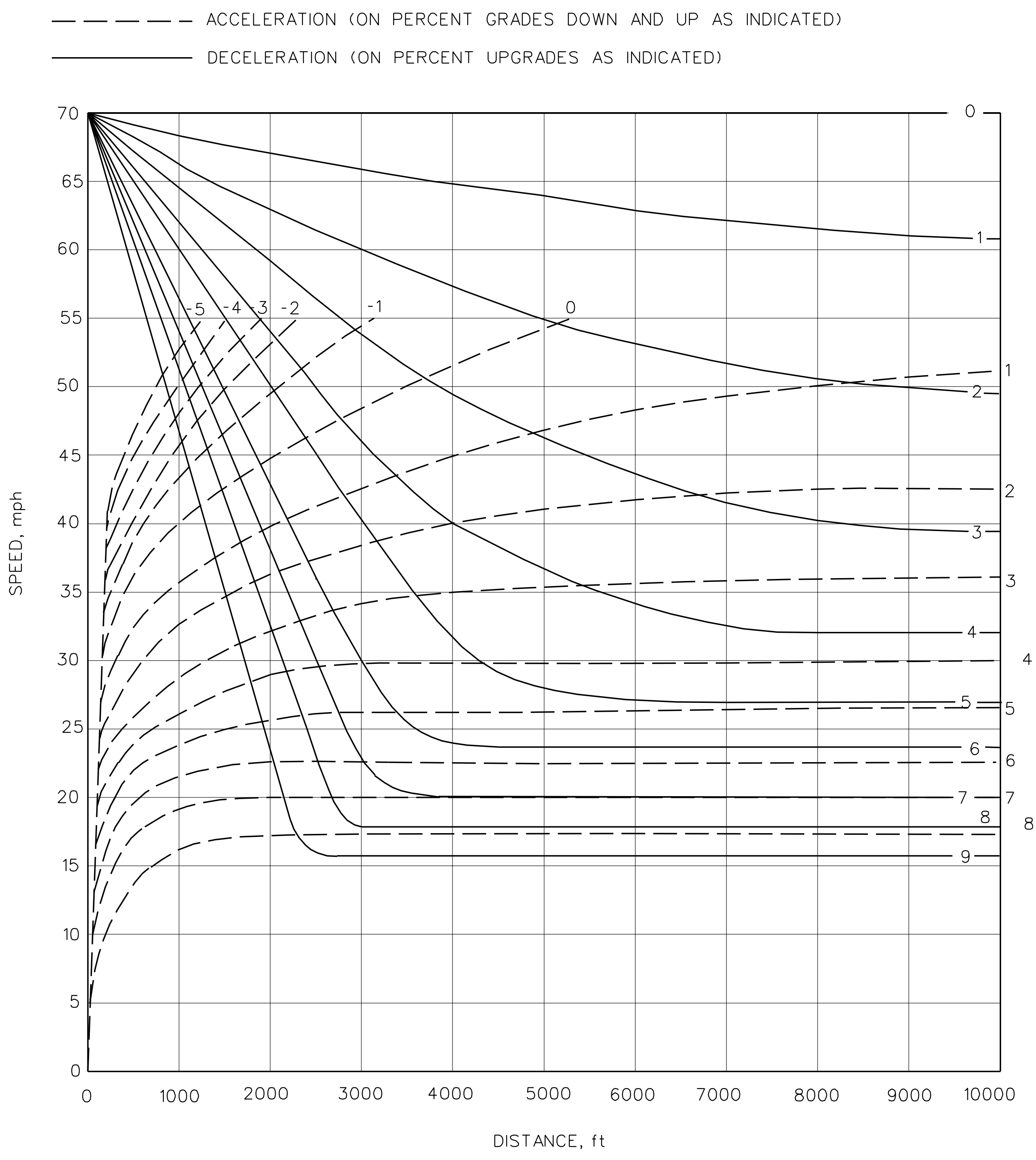
To determine if a climbing lane is warranted, these basic steps should be followed:

1. Review the project to determine if a climbing lane should be considered. Steep and/or long grades should be considered for climbing lanes.

2. For highways with a single grade, the critical length of grade can be directly determined from Figure 9-2A. However, most highways have a continuous series of grades. Often, it is necessary to find the impact of a series of significant grades in succession. If several different grades are present, then a speed profile must be developed using Figure 9-2C and the procedures set forth in the *Highway Capacity Manual*. If there is a 10 mph reduction, then the first warrant is met. The speed profile should note the truck speed at the beginning of the full-width climbing lane, the PVC, the PVT and the end of the full-width lane.

3. Determine the total traffic volumes, the truck volumes on the grade and those on the approach prior to the upgrade.

4. Using the procedures set forth in the *Highway Capacity Manual*, determine the appropriate level of service for both the approach and the grade. If the level of service on the upgrade is E/F or if there is a reduction of 2 or more levels of service on the upgrade from the approaches, then the second warrant is met.



Note: For design speeds above 70 mph use an initial speed of 70 mph. For design speeds 70 mph and below, use the design speed as the initial speed.

PERFORMANCE CURVES FOR LARGE TRUCKS
(200 lb/hp)

Figure 9-2C

9-2.04.03 Design

Figure 9-2D summarizes the design criteria for climbing lanes. It should be noted, that actual placement of the tapers for the beginning and end of climbing lanes should consider sight distance to the tapers. The placement of the terminal taper should maximize the available sight distance. The shoulder width along the climbing lane will be the normal shoulder width for the appropriate highway classification. The tables in Chapters Four and Five provide the shoulder widths.

The Traffic Standard Details provide the typical signing and pavement marking patterns for the climbing lanes.

Highway Type	Design				
	Begin Climbing Lane	End Climbing Lane	Taper Length (Begin/End)	Lane Width	Shoulder Width
Freeways	45 mph	50 mph	300 ft/600 ft	12 ft	Same as preceding roadway section.
Other Facilities	10 mph below design speed or 45 mph, whichever is less.	10 mph below design speed or 45 mph, whichever is less	25:1/(1)	See Chapters Four and Five	Same as preceding roadway section.

(1) The taper length on other facilities for ending the climbing lane will be determined by the following taper rates:

Design Speed (mph)	End Taper Rates
20	7:1
25	10:1
30	15:1
40	25:1
45	45:1
50	50:1
55	60:1
65	65:1
70	70:1
75	75:1

DESIGN CRITERIA FOR CLIMBING LANES

Figure 9-2D

9-3.0 VERTICAL CURVES

9-3.01 General

The principal concern in the design of crest vertical curves is to ensure that at least stopping sight distance is provided. Headlight sight distance will usually control the design of sag vertical curves. Two factors affect the availability of sight distance — the algebraic difference between gradients of the intersecting tangents and the length of the vertical curve. With a small algebraic difference in grades, the length of the vertical curve may be relatively short. To obtain the same sight distance with a large algebraic difference in grades, a much longer vertical curve will be necessary. If the grade break is 0.5 percent or less, then the designer may use an “angle” point (i.e., no vertical curve).

All vertical curves are in the shape of a parabola. Figure 9-3A illustrates the geometric details of a symmetrical vertical curve. Figure 9-3B provides an example of how to determine the elevations along a vertical curve.

9-3.02 Crest Vertical Curves

The basic equations for crest vertical curves are:

$L = KA$ *or* $L = 3V$, whichever is larger (Equations 9-3.1 and 9-3.2)

$$K = \frac{S^2}{200\left(\sqrt{h_1} + \sqrt{h_2}\right)^2} \quad \text{(Equation 9-3.3)}$$

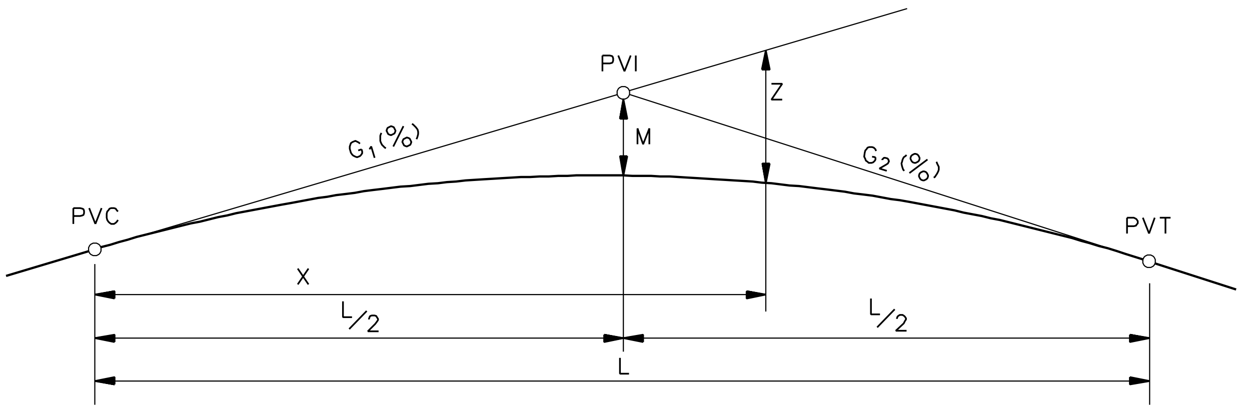
$$L = \frac{AS^2}{200\left(\sqrt{h_1} + \sqrt{h_2}\right)^2} \quad \text{(Equation 9-3.4)}$$

where:
- L = length of vertical curve (ft)
- A = absolute value of the algebraic difference between the two tangent grades (%)
- S = sight distance (ft)
- h_1 = height of eye above road surface (ft)
- h_2 = height of object above road surface (ft)
- K = horizontal distance needed to produce a 1% change in gradient

For the design of crest vertical curves, the following will apply:

1. Stopping Sight Distance. Stopping sight distance is the minimum design for crest vertical curves. A height of eye of 3.5 ft and a height of object of 2 ft are used. Using Equation 9-3.4, this yields the following equation:

$$L = \frac{AS^2}{2158} \quad \text{(Equation 9-3.5)}$$



M	=	Mid-ordinate (ft)
Z	=	Any tangent offset (ft)
L	=	Horizontal length of vertical curve (ft)
X	=	Horizontal distance from PVC or PVT to any ordinate "Z" (ft)
G_1 & G_2	=	Rates of grade, expressed algebraically (%)

Note: All expressions should be calculated algebraically.

Elevations of PVI and PVT:

$$PVI_{elev} = PVC_{elev} + G_1 \frac{L}{200}$$

$$PVT_{elev} = PVC_{elev} + (G_1 + G_2)\frac{L}{200}$$

2. For offset "Z" at distance "X" from PVC or PVT:

$$Z = M\left(\frac{X}{\frac{L}{2}}\right)^2 \quad \text{or} \quad Z = \frac{X^2\,(G_2 - G_1)}{200L}$$

SYMMETRICAL VERTICAL CURVE EQUATIONS

Figure 9-3A

3. For slope "S" of a line tangent to any point on the vertical curve at an "X" distance measured from the PVC:

$$S\,(\%) = G_1 - \left[X \left(\frac{G_1 - G_2}{L} \right) \right]$$

4. Calculating high or low point on curve:

$$X_T = \frac{LG_1}{G_1 - G_2}$$

Where:

X_T equals the horizontal distance from the PVC to the high or low point on the curve in feet.

5. Elevation of high or low point on curve:

$$ELEV_{\text{High or Low Point}} = PVC_{elev} - \frac{LG_1^{\,2}}{(G_2 - G_1)\,200}$$

SYMMETRICAL VERTICAL CURVE EQUATIONS
(Continued)

Figure 9-3A

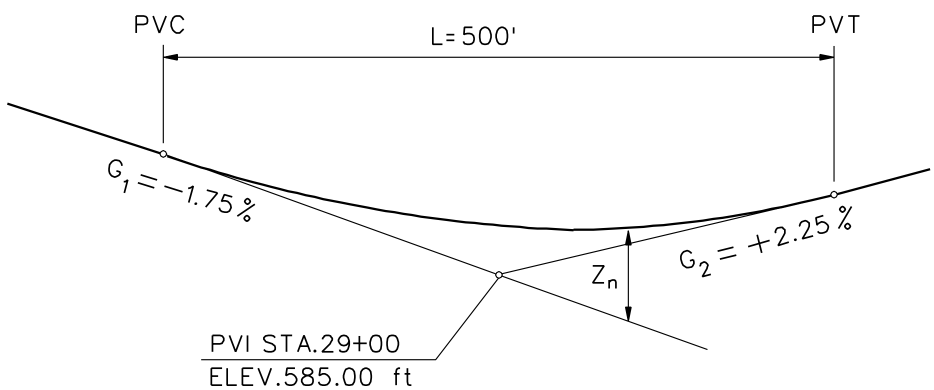
Example 9-3.1

Given: G_1 = -1.75%
G_2 = +2.25%
Elev. of PVI = 585.00 ft
Station of PVI = 29+00.00
L = 500 ft

Problem: Compute the grade for each 50-ft station. Compute the low point elevation and stationing.

Solution:

6. Draw a diagram of the vertical curve and determine the station of the beginning (PVC) and the end (PVT) of the curve.



Beginning Station (PVC) = PVI Sta – ½L = (29 + 00) - (0 + 250) = 26 + 50
End Station (PVT) = PVI Sta +½L = (29 + 00) + (0 + 250) = 31 + 50

7. From the vertical curve equations in Figure 9-3A:

$$M = \frac{(G_2 - G_1)L}{800} = \frac{[2.25 - (-1.75)]\,500}{800} = 2.5 \text{ ft}$$

$$Z = M\left(\frac{X}{L/2}\right)^2 = \frac{4M}{L^2}X^2 = \frac{(4)(2.5)}{250{,}000}X^2 = \frac{X^2}{25{,}000}$$

VERTICAL CURVE COMPUTATIONS
(Example 9-3.1)

Figure 9-3B

Example 9-3.1 (continued)

8. Set up a table to show the vertical curve elevations at the 50-ft stations:

Station (n)	Inf.	Tangent Elevation (Along G_1)	X	X^2	Z_n	Grade Elevation
26 + 50	PVC	589.38	0	0	0	589.38
27 + 00		588.50	50	2500	.100	588.60
27 + 50		587.63	100	10,000	.400	588.03
28 + 00		586.75	150	22,500	.900	587.65
28 + 50		585.88	200	40,000	1.600	587.48
29 + 00	PVI	585.00	250	62,500	2.500	587.50
29 + 50		584.13	300	90,000	3.600	587.73
30 + 00		583.25	350	122,500	4.900	588.15
30 + 50		582.38	400	160,000	6.400	588.78
31 + 00		581.50	450	202,500	8.100	589.60
31 + 50	PVT	580.63	500	250,000	10.000	590.63

4. Calculating low point:

$$X_T = \frac{LG_1}{G_1 - G_2} = \frac{500(-1.75)}{-1.75 - 2.25} = \frac{-875}{-4.00} = 218.75 \text{ ft from PVC}$$

therefore, the Station at low point equals:

(26 + 50) + (02 + 18.75) = (28 + 68.75)

and the elevation of low point on the curve equals:

$$ELEV_{LOW} = PVC_{elev} - \frac{LG_1^{\,2}}{(G_2 - G_1)\,200} = 589.38 - \frac{500(-1.75)^2}{(2.25 - (-1.75))\,200}$$

$$= 589.38 - 1.91 = 587.47 \text{ ft}$$

VERTICAL CURVE COMPUTATIONS
(Example 9-3.1)
(Continued)

Figure 9-3B

Figure 9-3C presents the K-values for crest vertical curves. These values have been calculated by using the SSD values from Figure 7-1A and Equation 9-3.6.

2. Grade Adjustments. When determining S for crest vertical curves, the designer should consider the effects of grade on stopping sight distance (SSD). The following thresholds may be used for determining the thresholds for “Level” K-values:

   $V \geq 50$ mph: $-1\% < G < +1\%$

   $V < 50$ mph: $-2\% < G < +2\%$

   The selection of “G” at a crest vertical curve will depend on which grade is steeper and whether the roadway is one-way or two-way. On a one-way roadway, “G” should always be the grade on the far side of the crest when considering the direction of travel. On a two-way roadway, “G” should always be the steeper of the two grades on either side of the crest.

   For design exception purposes, only the “Level” SSD value will require an exception. For designs where, because of rounding in the charts, the “Level” SSD is met but not the K-value, an exception will not be required.

3. Decision Sight Distance. Section 7-2.0 discusses the general warrants for decision sight distance. The procedure will determine the appropriate “S” and height of object for the specific site conditions. These values should then be used in Equation 9-3.3 to determine the necessary curve length at the site.

4. Drainage. Drainage should be considered in the design of crest vertical curves where curbed sections are used. Drainage problems should not be experienced if the vertical curvature is sharp enough so that a minimum longitudinal grade of at least 0.3% is reached at a point about 50 ft from either side of the apex. To ensure that this objective is achieved, the length of the vertical curve should be based upon a K-value of 167 or less. For crest vertical curves on curbed sections where this K-value is exceeded, the drainage design should be more carefully evaluated near the apex.

   For uncurbed sections of highway, drainage should not be a problem at crest vertical curves.

9-3.03 Sag Vertical Curves

Headlight sight distance is the primary design control for sag vertical curves. The height of the headlights is assumed to be 2.0 ft. The upward divergence of the beam is 1° from the longitudinal axis of the vehicle. The curvature of the sag should allow sufficient pavement illumination to provide adequate sight distance. These criteria yield the following equations:

$L = KA$ *or* $L = 3V$, whichever is larger (Equations 9-3.6 and 9-3.7)

Design Speed (mph)	Downgrades			Level	Upgrades		
	-9%	-6%	-3%	0%	+3%	+6%	+9%
20	8	7	7	7	6	6	6
25	15	13	12	12	11	10	10
30	25	22	20	19	19	16	15
35	39	35	32	29	27	25	24
40	59	52	46	44	39	37	34
45	86	75	67	61	56	52	48
50	121	105	94	84	76	71	66
55	164	143	126	114	103	94	88
60	221	190	169	151	136	123	114
65	290	247	218	193	176	159	148
70	372	316	279	247	221	202	187

Notes:

1. *For grades intermediate between columns, use a straight-line interpolation to calculate the K-value.*
2. *Only the "Level" SSD are applicable for design exception purposes.*
3. *Stopping sight distances (SSD) are from Figure 7-1A.*
4. *Maximum K-value for drainage on curbed roadways is 167; see Section 9-3.02.*
5. $K = \frac{S^2}{2158}$, *where* $h_1 = 3.5$ *ft,* $h_2 = 2.0$ *ft.*

K-VALUES FOR CREST VERTICAL CURVES

Figure 9-3C

$$K = \frac{S^2}{200\,h_3 + 3.5S} \qquad \text{(Equation 9-3.8)}$$

$$L = \frac{AS^2}{200\,h_3 + 3.5S} \qquad \text{(Equation 9-3.9)}$$

where:
- L = length of vertical curve (ft)
- A = absolute value of algebraic difference between the two tangent grades (%)
- S = sight distance (ft)
- h_3 = height of headlights (ft)
- K = horizontal distance needed to produce a 1% change in gradient

For the design of sag vertical curves, the following will apply:

1. Stopping Sight Distance (SSD). Figure 9-3D presents the K-values for sag vertical curves. These values have been calculated by using the SSD values from Figure 7-1A and Equation 9-3.8.

2. Grade Adjustments. Section 9-3.02 discusses the application of SSD to crest vertical curves pertaining to the grade correction. The grade correction and the thresholds also apply to sag vertical curves.

   For design exception purposes, only the "Level" SSD value will require an exception. For designs where, because of rounding in the charts, the "Level" SSD is met but not the K-value, an exception will not be required.

3. Decision Sight Distance. Section 7-2.0 discusses the general warrants for decision sight distance. The procedure will determine the appropriate "S" and height of object for the specific site conditions. These values should then be used in Equation 9-3.9 to determine the necessary curve length at the site.

4. Drainage. Drainage considerations also impact the design of sag curves. The criteria is the same as for crest vertical curves, which yields a K = 167 for the maximum length of curve. Where this K value is exceeded, the designer should consider special drainage treatments, especially on curbed pavements. In addition, the designer should avoid the placement of bridges or other structures at the low point of sag vertical curves because of the potential drainage problems.

Design Speed (mph)	Downgrades			Level	Upgrades		
	-9%	-6%	-3%	0%	+3%	+6%	+9%
20	20	18	18	17	16	16	15
25	31	28	27	26	25	24	22
30	44	41	38	37	37	33	32
35	60	56	52	49	47	44	43
40	77	72	66	64	60	57	55
45	97	89	84	79	74	72	68
50	119	110	103	96	91	87	83
55	143	132	122	115	108	103	99
60	170	156	144	136	128	121	115
65	198	181	168	157	149	140	135
70	227	207	193	181	170	161	154

Notes:

1. *For grades intermediate between columns, use a straight-line interpolation to calculate the K-value.*
2. *Only the "Level" SSD's are applicable for design exception purposes.*
3. *Stopping sight distances (SSD) are from Figure 7-1A.*
4. *Maximum K-value for drainage on curbed roadways and bridges is 167; see Section 9-3.03.*
5. $K = \frac{S^2}{400 + 3.5S}$, *where* h_3 *= 2.0 feet.*

K VALUES FOR SAG VERTICAL CURVES

Figure 9-3D

9-4.0 VERTICAL CLEARANCES

Figure 9-4A summarizes the minimum vertical clearances for new bridges for various highway classifications and conditions.

Type	Clearance
Freeway or Expressway Under	16′-3″ over the entire roadway width (1) (2)
Arterial Under	16′-3″ over the entire roadway width (1)
Collector Under	14′-6″ over the entire roadway width (1)
Local Under	14′-6″ over the entire roadway width (1)
Railroad Under Highway	22′-6″ from the top of the rail to the bottom of the structure (electrified only); 20′-6″other railroads (5)
Railroad Under Freeway	23′-0″ from the top of the rail to the bottom of the structure
Highway Under Sign Structure (includes sign) or Pedestrian Bridge	17′-3″ over the entire roadway width
Parkway Under	14′-6″ over the entire roadway width

Notes:

1. *Table values allow 3* in *for resurfacing.*
2. *The minimum vertical clearance beyond the edge of shoulder must be sufficient to accommodate a* 14′-3″*vehicle in height by 8.5 ft in width. On the Interstate system, the minimum vertical clearance is 16'-3" beyond the edge of shoulder.*
3. *For vertical clearances in the vicinity of airports, see 23 CFR 620 which discusses airspace management on Federal-aid highways.*
4. *Department practice is to post a "low-clearance" sign on structures with vertical clearances less than or equal to* 14′-3″*.*
5. *Exceptions to the vertical clearances over railroads require approval from the Connecticut Legislature and ConnDOT.*

MINIMUM VERTICAL CLEARANCES
(New Bridges)

Figure 9-4A

9-5.0 REFERENCES

1. *A Policy on Geometric Design of Highways and Streets*, AASHTO, 2001.

2. *Highway Capacity Manual 2000*, TRB, 2000.